DEPARTMENT OF FISH AND GAME
ENVIRONMENTAL SERVICES DIVISION
Stream Flow and Habitat Evaluation Program

FALL-RUN CHINOOK SALMON SPAWNER ESCAPEMENT SURVEY
MAINSTEM SACRAMENTO RIVER
October - December 1995

Prepared by

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2/ Stream Evaluation Program Technical Report 96-6.

INTRODUCTION

The California Department of Fish and Game's (DFG) Stream Flow and Habitat Evaluation Program (SF&HEP) conducted an intensive fall-run chinook salmon escapement survey on the mainstem Sacramento River during the fall-winter of 1995 to estimate fall-run chinook salmon spawner abundance and distribution. This survey was carried out to accommodate the mandates of Section 3406(b)(1)(B) of the Central Valley Project Improvement Act (CVPIA), P.L. 102-575, that requires the Secretary of the Interior to determine instream flow needs for all Central Valley Project controlled streams and rivers. Flow-need recommendations are to be provided to the Secretary by the U. S. Fish and Wildlife Service (FWS) after consultation with DFG. In response to this Act, the FWS and the DFG entered a "Cooperative Agreement" to determine flow needs of anadromous salmonids in the mainstem Sacramento River.

The primary mission of the SF&HEP - to improve understanding of the relationships between salmon and habitat in the mainstem Sacramento River - requires reliable estimates of the spawner population to help distinguish habitat versus population influences on temporal and spatial spawning distribution (Snider and McEwan 1992, Snider *et al*. 1993, and Snider and Vyverberg 1995). Changes in spawning activity related to changes in flow and temperature need to be distinguished from changes due to population size. Spawning density, redd superimposition, habitat use, and other parameters can be affected by both changes in habitat conditions (flow dependent) and spawner population size. A reliable population estimate developed concurrently with redd surveys should allow this distinction. An intensive spawner escapement survey also provides additional baseline information on egg retention (pre-spawning mortality), age and sex composition, and behavior relative to habitat conditions and population size.

HISTORICAL BACKGROUND

Salmon spawner surveys were first conducted in the mainstem Sacramento River in 1937 to evaluate the potential effect of Shasta Dam on chinook salmon. From 1937 through 1942, salmon were counted as they passed through a fish ladder at Anderson-Cottonwood Irrigation District's (ACID) dam (river mile), near Redding (Fry 1961) (Needham et. al.1943). The counts were made to determine the number of fish that would be blocked by Shasta Dam. The counts were made by the Division of Fish and Game (became the Department of Fish and Game in 1952) in 1937, the U. S. Bureau of Reclamation from 1938 through 1941, and the FWS in 1942. ACID Dam is a low, flash board dam that is typically installed in April and is maintained until October or early November. During both installation and dismantling, fish could jump over the flash boards and avoid being counted. Excessively high spring flows sometimes delayed installation of the flash boards and prevented counts.

From 1943 through 1945, salmon spawner counts on the mainstem were made at Balls Ferry (river mile 276). A rack was built for counting and trapping salmon. It was also intended to force part of the population to spawn downstream to reduce spawning density between Balls Ferry and

the recently constructed Keswick Dam (river mile 302). Many fish passed this rack uncounted during periods of high flows and by moving through holes underneath the rack.

Fry (1961) concluded that the 1940's spawner escapement estimates for the mainstem were probably much lower than the actual population. This was due to both the tendency to overrate the ability to observe, thus count fish moving through the weir, even when visibility seemed excellent, and to underestimate how many salmon went through small holes in the counting weir. From 1946 through 1952 a variety of methods were used by both the DFG and FWS to estimate salmon spawning escapement to the mainstem. Both ground and aerial surveys were made to count carcasses and redds. The estimates were substantially based upon these data and "professional judgement" using the experience of individuals associated with the program. These estimates were never tested against other methods or counts.

DFG also used a tag-and-recovery method from the 1950 through 1955 to estimate populations in the mainstem Sacramento River (Fry 1961). Live fish were captured in fyke traps located downstream of the spawning grounds, at Fremont Weir (river mile 84), then tagged and released. The tags were later recovered from the carcasses during spawning area surveys, upstream of river mile 200. This method was satisfactory on the American and Stanislaus rivers, but proved much less satisfactory on the mainstem Sacramento River (Fry 1961). He gave the following reasons for this method being unsatisfactory: (I) the difficulty of recovering adequate numbers of spawned-out carcasses; (ii) the trapping site was too far below the spawning area; and (iii) the trap selected for smaller fish.

From 1956 through 1968, spawner estimates were made by experienced DFG biologists using carcass counts(no tag-recapture estimates were made), aerial redd counts, and comparisons with previous years' observations (Dick Hallock, pers. comm). Turbidity, flow, and number of survey trips were integrated into the estimate. Using the estimate and the carcass counts, carcass "recovery" was estimated to range from 0.7 to 4.0%.

Beginning in 1969, estimates were based on fish counts made at the fish ladders on Red Bluff Diversion Dam (RBDD) at river mile 243 (Menchen 1970). The counts were adjusted for periods when no counts were made, including when the dam was open due to normal operation or during floods, and during night hours when no counts were made. The estimated number of fish caught by anglers was subtracted from the number passing over RBDD to calculate spawner escapement. Aerial redd counts were used to determine the distribution of spawning upstream and downstream of RBDD. These results were used to expand RBDD counts and calculate a total estimate for the entire mainstem.

Since 1986, the gates at RBDD have been raised in the fall and lowered during the following spring to improve fish passage. Since 1994, the gates are normally open between September 15th and May 15th. Direct (fishway) counts cannot be made when the gates are raised. Salmon spawner estimates are now computed by dividing the number of fish counted in the fishway by the estimated portion of the total run represented in the counting period. The estimated portion was based on historical data when counts were made year around.

The 1995 escapement survey represents the first attempt since 1968 to estimate salmon spawner escapement in the mainstem Sacramento River based on the ground surveys. It also represents the first attempt ever in the mainstem to use carcasses and a tag-recapture model to estimate spawner escapement.

When monitoring stocks over a long period, such as the Central Valley salmon escapement surveys, the sampling design should assure the data be collected in a consistent manner and represent the population as a whole (Ney 1993). Inconsistencies in methods before 1968 were primarily due to changes in funding that often reduced or eliminated sampling effort, thus the data used to make estimates. Also, population estimates were often based on counts made upstream of where varying portions of the salmon population would spawn - ACID Dam, Balls Ferry Racks, and RBDD. This limited the ability to consistently estimate the entire spawning population unless spawning distribution was also measured. Another limitation was the unknown number of fish that could migrate uncounted above the counting sites. This prompted Fry and Petrovich (1970) to conclude: "Until we can determine the magnitude of salmon movement through the gates at the Red Bluff Dam the counts there cannot be regarded as more than an index."

OBJECTIVES

- To estimate the 1995, in-river, fall-run chinook salmon spawning population for the mainstem Sacramento River.

- To augment redd surveys to provide baseline information on spawning distribution, spawning habitat availability, instream flow requirements, and the status of chinook salmon in the mainstem Sacramento River.

METHODS

A carcass tag-and-recapture study was conducted in the mainstem Sacramento River during fall-winter 1995 to estimate fall-run chinook salmon spawner escapement. The study section extended 25.5 miles from ACID Dam downstream (river mile 298.5) to Cottonwood Creek (river mile 273) (Figure 1). Carcasses were tagged and released into running water for later recapture, unlike the earlier tag-and-recovery study when live fish were tagged and released at Fremont weir. Carcass tag-and-recapture studies along with use of the Schaefer or Jolly-Seber models have been regularly used to estimate escapements in other Central Valley tributary streams (e.g., American, Yuba, and Feather rivers). This protocol was initially used in the Central Valley to estimate the 1973 Yuba River escapement (Taylor 1974).

Three models have been used by the DFG to estimate escapement from carcass tag-and-recovery data: Petersen (Ricker 1975), Schaefer (1951) and the Jolly-Seber (Seber 1982). The Petersen model is the simplest but least accurate (Law 1992). It has been used primarily when data are

insufficient to allow calculation with other models. It is occasionally used to estimate escapement to smaller tributary streams (e.g. Cosumnes, Merced, Stanislaus, and Tuolumne rivers). A modification of the Schaefer model has been used in "larger" Central Valley tributary streams since 1973 when it was first used to estimate the Yuba River escapement. This model was first used to estimate escapement in the Central Valley in 1988. The Jolly-Seber model is more accurate when model assumptions are met and recovery rates are $\geq$ 10% (Boydstun 1992 and Law 1992). Still, there is considerable disagreement among fisheries managers responsible for estimating spawner escapement for California streams. They believe that population estimates obtained by the Jolly-Seber model are too low (Fisher and Meyer, pers. comm.). Law (1992) states that both models could produce low estimates if the basic assumption of equal mixing of tagged carcasses with all carcasses is violated, resulting in the recaptured carcasses constituting a different subpopulation.

The escapement survey began on October 1, immediately following initiation of spawning activity, and continued through December 23, 1995. The study reach from Acid Dam to Cottonwood Creek was surveyed weekly (Figure 1). This reach was further divided into four reaches and each reach was surveyed one day per week (Table 1).

The carcass tag-recapture study was conducted to provide estimates using both the Schaefer and Jolly-Seber models. Complete carcasses (i.e., with the head in tact) were normally tagged. Carcasses that were chopped (not tagged) included: I) those on shore in a "leathery condition"; ii) those in Reach 4 (the most downstream reach) that would likely wash out of the survey area and never be recovered; and iii) carcasses in excess of the number crews could tag during a day. "Fresh" and "decayed" carcasses were combined to calculate estimates for both the Schaefer and Jolly-Seber models. Data acquired weekly for estimating population size included number tagged, number chopped, and number recovered (by week of tagging). Unfortunately, only the number recovered data were collected during the last two survey weeks. This error resulted in a slight underestimate of the population for those two weeks. Since the error occurred during the end of spawning, when the population was relatively very low, it only slightly affected the overall spawner population estimate.

Data collected from a subsample of the fresh carcasses included sex, fork length (FL) in centimeters, reach of the stream that each carcass was observed, and egg retention for females. Females were classified as spent if few eggs were remaining, partially spent if more than 50% of the eggs remained, and unspent if the ovaries were nearly full of eggs.

Table 1. Location of survey reaches for the mainstem Sacramento River fall-run chinook salmon escapement survey, October 1995 - December 1995.

Reach	Location	River mile
1	ACID Dam to Cypress St. Bridge	298.5 - 295.0
2	Cypress St. Bridge to Bonnyview Bridge	295.0 - 292.0
3	Bonnyview Bridge to North St. Bridge	292.0 - 284.0
4	North St. Bridge to Cottonwood Cr.	284.0 - 273.0

RESULTS

A total of 8,653 carcasses (adults and grilse) was observed (Table 2). Temperature ranged from 53 ^{o}F during week 12 to 57 ^{o}F during week 7. Flows were 6,500 cfs during the first week; 5,400 cfs during the second survey week; and 4,800 cfs during the remainder of the survey (Figure 2).

Temporal Distribution

The number of carcasses observed steadily increased from the first week, peaked in the sixth week (November 5-10), and then declined each week afterwards (Table 3 and Figure 3).

Table 2. General survey information for the mainstem Sacramento River fall-run chinook salmon spawner escapement survey, October 1995 - December 1995.

Week	Dates	Flows (cfs)[1/]	Water temperature (°F)[2/]	Carcass count[3/]
1	Oct 1 - 7	6,500	55	55
2	Oct 8 - 14	5,400	55	240
3	Oct 15 - 21	4,800	55	602
4	Oct 22 - 28	4,800	54	969
5	Oct 29 - Nov 4	4,800	56	1,492
6	Nov 5 - 11	4,800	56	1,619
7	Nov 12 - 18	4,800	57	1,523
8	Nov 19 - 25	4,800	56	993
9	Nov 26 - Dec 2	4,800	55	753
10	Dec 3 - 9	4,800	56	500
11	Dec 10 - 16	4,800	54	7[4/, 5/]
12	Dec 17 - 23	4,800	53	5/
			Total	8,753

1/ Measured discharge at Keswick Dam, US Bureau of Reclamation.
2/ Weekly average of measurements recorded at Balls Ferry for days sampled.
3/ Includes both adults and grilse
4/ These were fresh carcasses measured and examined for ripeness but not included in the tag-and-recapture study.
5/ Only tag recaptures were recorded during weeks 11 and 12.

Spatial Distribution

The greatest portion (40%) of carcasses was observed in Reach 1 (Table 3 and Figure 4). Twenty-one percent were observed in Reach 2, 23% in Reach 3, and 16% in Reach 4.

Table 3. Summary of carcass distribution (adults and grilse) during the mainstem Sacramento River fall-run chinook salmon spawner escapement survey, October - December 1995.

Week	Reach 1		Reach 2		Reach 3		Reach 4	
	M[1/]	C[2/]	M	C	M	C	M	C
1	25	0	24	0	6	0	0	0
2	100	2	46	0	60	5	26	1
3	209	29	120	11	115	10	101	7
4	311	36	187	12	216	20	165	22
5	457	52	282	46	320	49	249	37
6	556	49	247	37	349	50	271	60
7	445	76	265	85	286	76	210	80
8	418	116	168	60	188	43	3/	3/
9	220	113	69	62	86	49	99	55
10	205	78	69	36	70	42	3/	3/
11	4/	7[4/,5/]	4/	4/	4/	4/	4/	4/
12	4/	4/	4/	4/	4/	4/	4/	4/
Total	2,946	551	1,477	349	1,696	344	1,121	262

1/ Number of carcasses tagged.
2/ Number of untagged carcasses chopped.
3/ No surveys were conducted.
4/ Only tag recaptures were recorded during weeks 11 and 12.
5/ Not included in the tag-and-recapture study.

Size Distribution

We measured 481 fresh carcasses (Table 4). The sample mean size was 81.1 cm FL. Size ranged from 47 to 111 cm FL. Male salmon averaged 84.0 cm FL (range: 47 - 111 cm FL). Female salmon averaged 79.9 cm FL (range: 54 - 104 cm FL).

Length frequency distributions were used to define a general size criterion distinguishing grilse (2-year-old salmon) and adult (>2-year-old salmon) for both sexes (Figures 5 and 6). Male (n=36) and female grilse (n=7) were defined as salmon $\leq$ 64 cm FL (Table 5). Male grilse averaged 57.9 cm FL (range: 47 - 64 cm FL, SD=4.6); male adults (n=147) averaged 87.3 cm FL (range: 65 - 111 cm FL, SD=9.1). Female grilse averaged 59.0 cm FL (range: 54 - 64 cm FL, SD=3.5); female adults (n=291) averaged 79.4 FL (range: 65 - 104 cm FL, SD=5.9).

The mean weekly size for females ranged from 77.7 to 87.4 cm FL (Table 4 and Figure 7). Mean weekly size for males ranged from 77.9 to 93.0 cm FL (Figure 8).

Grilse comprised 9% (43) of the 481 measured carcasses (Table 6). The greatest number of grilse (15) was observed in the forth week (October 22-28) (Figure 9). Most grilse were observed during the early weeks with very few seen after week 8.

Sex Composition

Males comprised 38% (183) of the fresh carcasses examined; 147 (80%) were adults and 36 (20%) were grilse (Table 7). Females comprised 62% (298) of the fresh carcasses examined, 291 (98%) were adults, and 7 (2%) were grilse. Male grilse comprised 84% (36) of the grilse observed and female grilse comprised 16% (7).

The ratio of female to male adult spawners was nearly 2:1 (291:147) (Table 7 and Figure 10). Most of the adult population consisted of females during the period sex composition was observed (weeks 4 though 11), while the grilse population was mostly males (Figure 11).

Spawning Success

We examined 231 females for egg retention (Table 8). Ninety four percent (217) had completely spawned, 3% (7) had not spawned, and 3% (7) had only partially spawned. Completely spawned females comprised more than 90% of the total females observed during weeks 4 through 10.

Table 4. Size and sex for fall-run chinook salmon carcasses measured during the mainstem Sacramento River chinook salmon spawner escapement survey, October - December 1995.

Week[1/]	All salmon			Male salmon			Female salmon		
	Number measured	Length (FL in cm)		Number measured	Length (FL in cm)		Number measured	Length (FL in cm)	
		Mean	Range		Mean	Range		Mean	Range
4	112	78.9	47-109	45	77.9	47-109	67	79.6	56-104
5	66	80.5	60-103	12	90.2	84-103	54	78.3	60-96
6	100	80.3	55-108	44	81.9	55-85	56	79.0	57-90
7	82	79.2	54-98	30	81.8	55-102	52	77.7	54-88
8	47	79.0	49-99	23	79.9	49-99	24	78.1	68-85
9	36	80.8	55-99	14	82.8	55-99	22	79.6	71-91
10	31	81.3	50-98	13	84.4	50-98	18	79.1	65-88
11	7	89.0	75-111	2	93.0	75-111	5	87.4	83-90
Total(mean)	481	81.1	47-111	183	84.0	47-111	298	79.9	54-104

1/ Fork length data were not obtained for weeks 1 - 3.

Table 5. Summary of adult and grilse size and numbers by sex for carcasses measured during the mainstem Sacramento River fall-run chinook salmon spawner escapement survey, October - December 1995.

	Female		Male	
	Grilse	Adult	Grilse	Adult
Number	7	291	36	147
Mean FL (cm)	59.0	79.4	57.9	87.3
Range FL (cm)	54-64	65-104	47-64	65-111
Standard deviation	3.5	5.9	4.6	9.1

Table 6. Age composition (grilse and adult) of carcasses measured during the mainstem Sacramento River fall-run chinook salmon spawner escapement survey, October - December 1995.

Week	Adults		Grilse	
	Number	Percent	Number	Percent
4	97	87	15	13
5	63	95	3	5
6	88	88	12	12
7	76	93	6	7
8	42	89	5	11
9	35	97	1	3
10	30	97	1	3
11	7	100	0	0
Total(mean)	438	(91)	43	(9)

Table 7. Sex composition of fall-run chinook salmon grilse and adult carcasses measured during the mainstem Sacramento River chinook salmon spawner escapement survey, October - December 1995.

Week[1/]	Grilse[2/]				Adult			
	Male		Female		Male		Female	
	Number	%	Number	%	Number	%	Number	%
4	13	11	2	2	32	29	65	58
5	0	0	3	5	12	18	51	77
6	11	11	1	1	33	33	55	55
7	5	6	1	2	25	30	51	62
8	5	11	0	0	18	38	24	51
9	1	3	0	0	13	36	22	61
10	1	3	0	0	12	39	18	58
11	0	0	0	0	2	29	5	71
Total(mean)	36	(7)	7	(1)	147	(31)	291	(61)

1/ No lengths were takes during weeks 1 - 3.
2/ Grilse are defined as $\leq$ 64 cm FL .

Table 8. Spawning completion (egg retention) summary for female carcasses measured during the mainstem Sacramento River fall-run chinook salmon spawner escapement survey, October - December 1995.

Week	# females checked for egg retention	Spawned Number (%)	Partially spawned Number (%)	Unspawned Number (%)
5	54	49 (91)	3 (6)	2 (3)
6	56	55 (98)	0 (0)	1 (2)
7	52	49 (94)	2 (4)	1 (2)
8	24	22 (92)	1 (4)	1 (4)
9	22	21 (95)	0 (0)	1 (5)
10	18	17 (94)	1 (6)	0 (0)
11	5	4 (80)	0 (0)	1 (20)
Total(mean)	231	217 (94)	7 (3)	7 (3)

Population Estimates

A total of 6,978 adult carcasses was tagged from Week 1 through Week 10. Thirty-three percent (2,287) were subsequently recaptured. The same carcass tag-and-recapture data (fresh and decayed carcasses) were used in the Schaefer and Jolly-Seber models to calculate an adult escapement estimate in the mainstem Sacramento River between ACID Dam and Cottonwood Creek (Table 9).

An estimate of 24,159 adult spawners was calculated using the Schaefer model (Table 10). Adults made up 91% of the total escapement based on carcasses measured (Table 6). A total escapement estimate of 26,546 spawners (adults and grilse) was calculated by dividing the adult estimate by 0.91. An adult escapement estimate of 17,237 was calculated using the Jolly-Seber model. This estimate also was expanded by dividing by 0.91 resulting in a total escapement estimate of 18,942 spawners.

The population estimates for salmon spawning in the mainstem Sacramento River from ACID Dam to Cottonwood Creek are as follows:

	Schaefer model	Jolly-Seber model
Total estimate	26,548	18,942
Adult estimate	24,159	17,237
Grilse estimate	2,389	1,705

The 1995 escapement of 26,548 is considerable less than the 1956-1994 average of 69,823 for the section of stream from Keswick Dam to RBDD (Table 11 and Figure 12). Based upon aerial redd surveys, most mainstem salmon spawning above RBDD occurs in the section between ACID Dam and Cottonwood Creek (Fisher pers. comm.)

DISCUSSION

Several of the procedures used during the 1995 fall-run survey should be changed to increase accuracy of the population estimates. The combining of the fresh and decayed carcass recoveries as was done in 1995 tends to inflate the population estimate calculated from the Schaefer model (Law 1992).

The stream reach from ACID Dam upstream to Keswick Dam was not surveyed in 1995. Normally less than 8% of the fall-run salmon that spawn in the mainstem above RBDD, do so in this reach (based on distribution from aerial redd counts). Up to 20% may have spawned there in 1985. Many of the carcasses of fish that spawn above ACID Dam likely wash downstream of the dam and would have been observed during our survey.

Based on Law's analysis (Law 1992), the Schaefer model will over estimate escapement when carcass "survival" (carry-over from week-to-week) and recovery rates are equivalent to those observed on the mainstem Sacramento River during 1995. Similarly, based on Law's (1992) analysis, the Jolly-Seber model will slightly under estimate the mainstem Sacramento River escapement.

We recommend that the following changes be included in future survey efforts to improve population estimates:

1. Categorize all tagged carcasses as fresh or decayed. When the tagged carcasses are later recovered, note how they were originally categorized.

2. Note all carcasses (tagged and untagged) observed during last 2 weeks of the survey.

3. Survey reach of stream from Keswick Dam downstream to ACID Dam.

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Table 9. Summary of tagging and recapture of adult carcasses by week, during the mainstem Sacramento River fall-run chinook salmon spawner escapement survey, October - December 1995.

Week of tagging	Number tagged	Number recaptured											Total recaptured
		Week of recapture											
		2	3	4	5	6	7	8	9	10	11	12	
1	47	9	0	4	2								15
2	219		84	13	10	1							108
3	524			145	46	10	3						204
4	779				231	77	16						324
5	1,284					367	80	12					459
6	1,382						374	79	14	1			468
7	1,180							253	70	10			333
8	763								184	43	2	1	230`
9	464									94	8	2	104
10	336										34	8	42
Total	6,978	9	84	162	289	455	473	344	268	148	44	11	2,287

Table 10. Adult population estimate matrix using the Schaefer Method during the mainstem Sacramento River fall-run chinook salmon spawner escapement survey, October 1995 - December 1995.

Week of recovery	Weekly adult population estimates										Totals
	1	2	3	4	5	6	7	8	9	10	
1											
2	739										739
3	0	1,348									1,348
4	80	168	2,370								2,618
5	38	123	718	3,377							4,256
6		9	115	827	4,587						5,538
7			32	160	932	4,600					5,724
8					129	899	3,456				4,484
9						156	936	2,303			3,394
10						13	153	617	1,814		2,596
11								7	36	272	314
12								3	9	64	76
Subtotal	857	1,649	3,236	4,364	5,649	5,668	4,545	2,929	1,858	336	31,090
Tagged		-219	-524	-779	-1,284	-1,382	-1,180	-763	-464	-336	-6,931
							Population estimate				24,159

Table 11. Fall-run chinook salmon escapement estimates (adults and grilse), mainstem Sacramento River from Keswick Dam to Red Bluff Diversion Dam, 1956 - 1994. (Data provided by Frank Fisher, Department of Fish and Game, Red Bluff)

Year	Total	Year	Total
1956	84,716	1976	43,612
1957	47,300	1977	15,784
1958	99,300	1978	32,235
1959	249,600	1979	47,758
1960	210,000	1980	21,961
1961	134,700	1981	26,261
1962	115,500	1982	17,731
1963	135,200	1983	26,226
1964	140,500	1984	36,898
1965	98,900	1985	51,647
1966	107,900	1986	67,958
1967	78,100	1987	76,039
1968	95,600	1988	65,204
1969	114,600	1989	48,512
1970	65,950	1990	32,225
1971	52,247	1991	19,272
1972	33,559	1992	26,912
1973	40,424	1993	33,923
1974	45,590	1994	31,017
1975	52,248		

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FIGURES

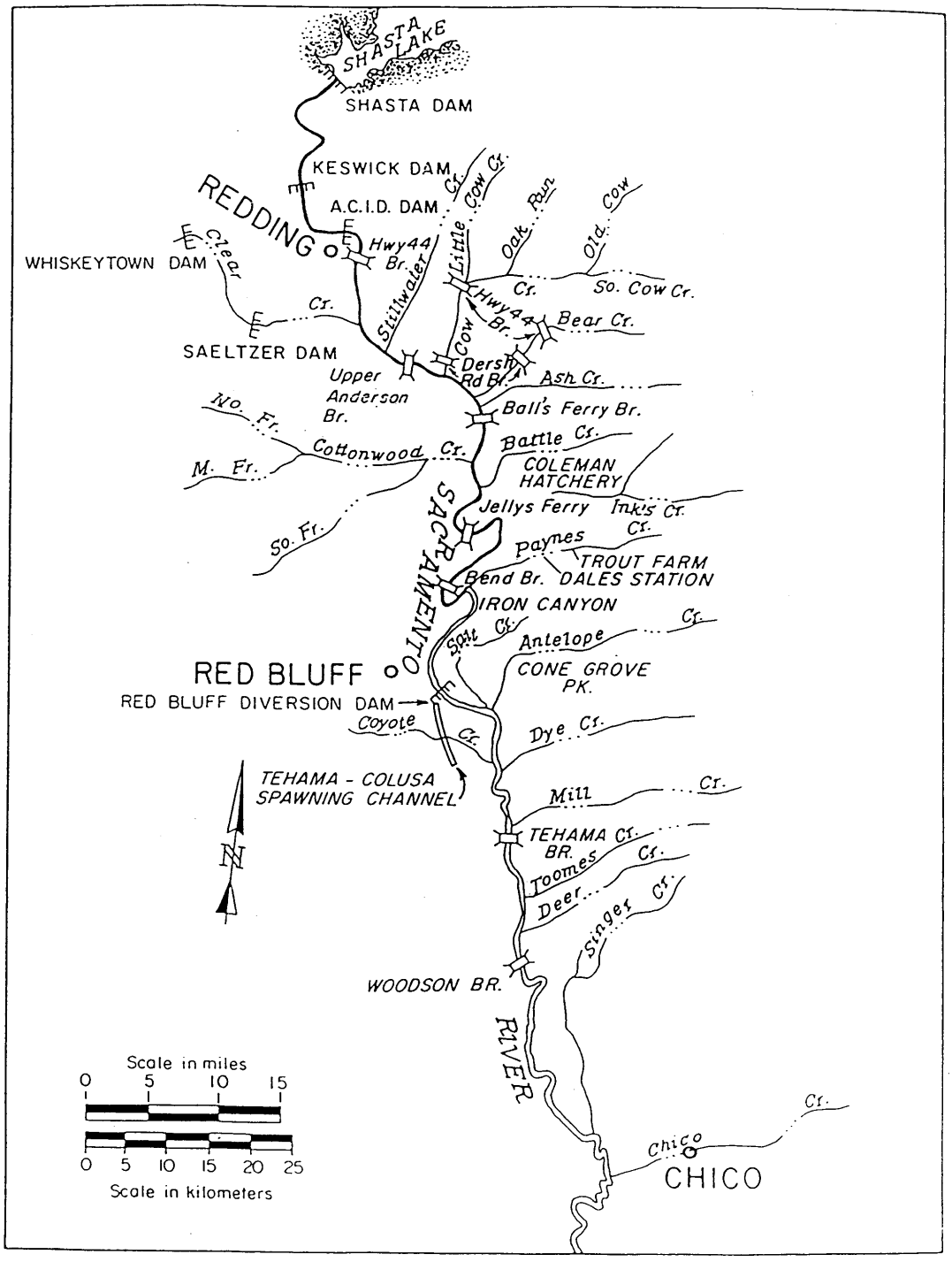

Figure 1. Upper Sacramento River.

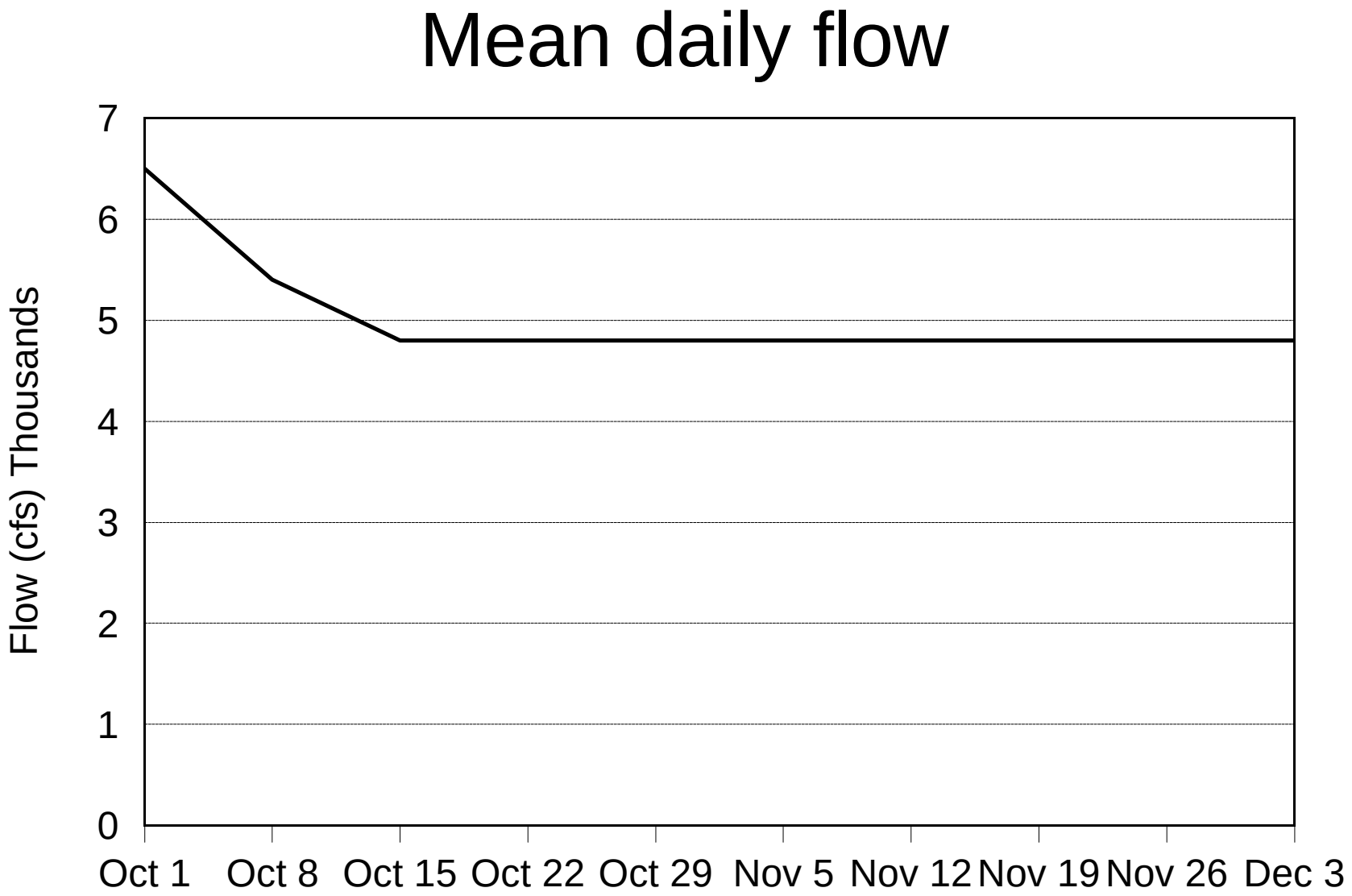

Figure 2. Mean daily flow measured at Keswick Dam during the 1995 upper Sacramento River fall-run chinook salmon spawner escapement survey, October - December 1995.

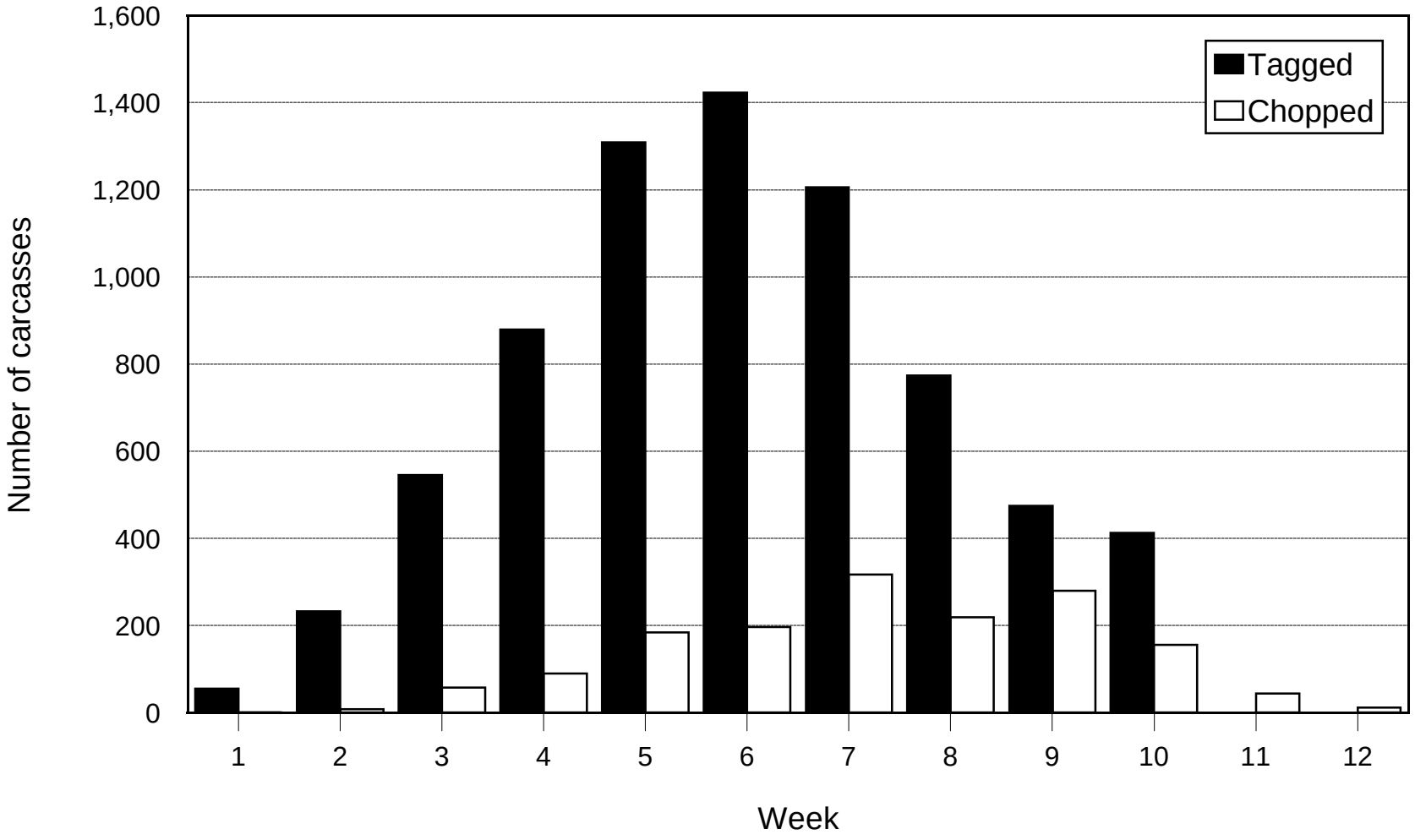

Figure 3. Weekly carcass distribution observed during the upper Sacramento River fall-run chinook salmon spawner escapement survey, October - December 1995.

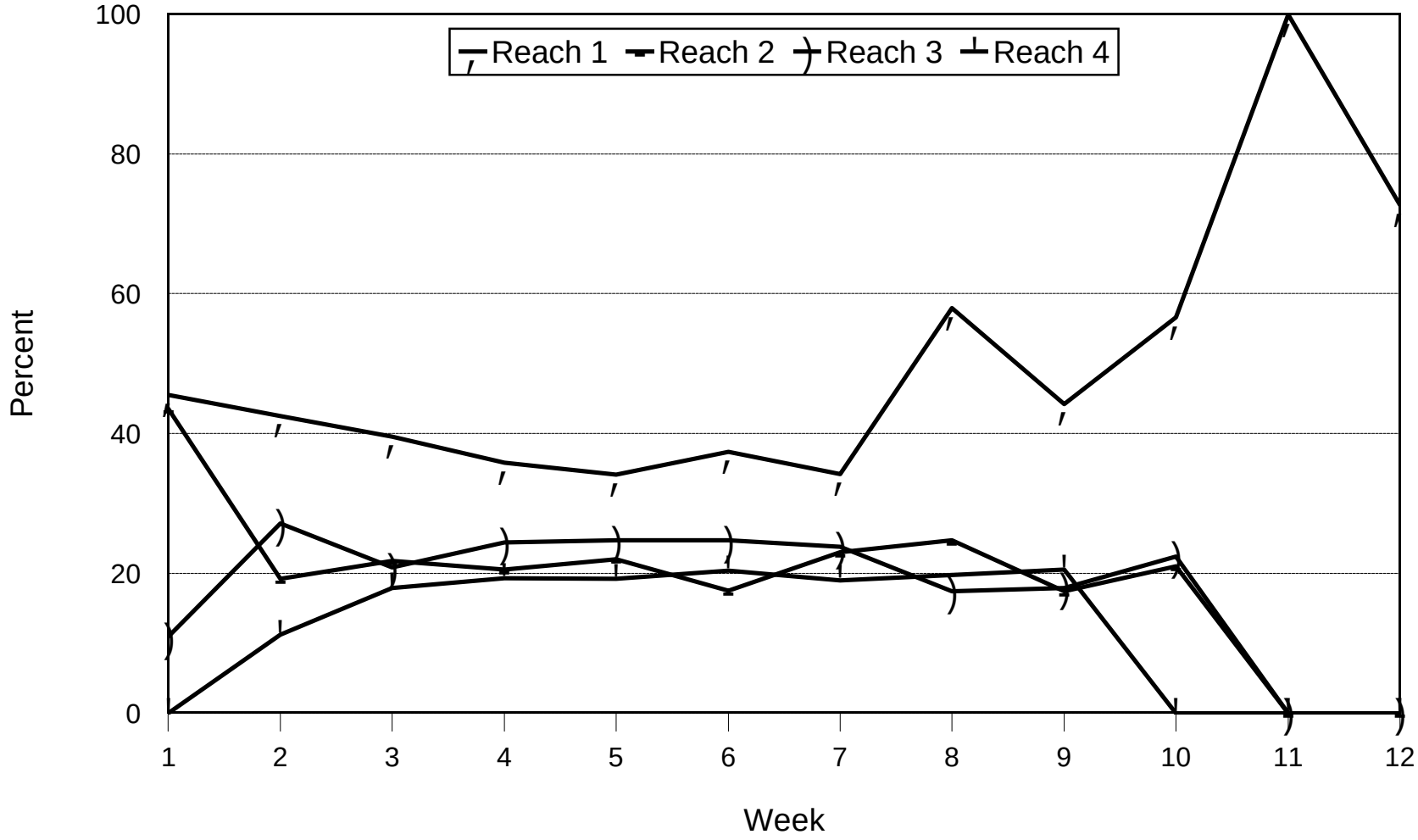

Figure 4. Weekly carcass distribution (percent by reach) observed during the upper Sacramento River fall-run chinook salmon spawner escapement survey, October - December 1995 (No observations made during weeks 8 and 10 in Reach 4).

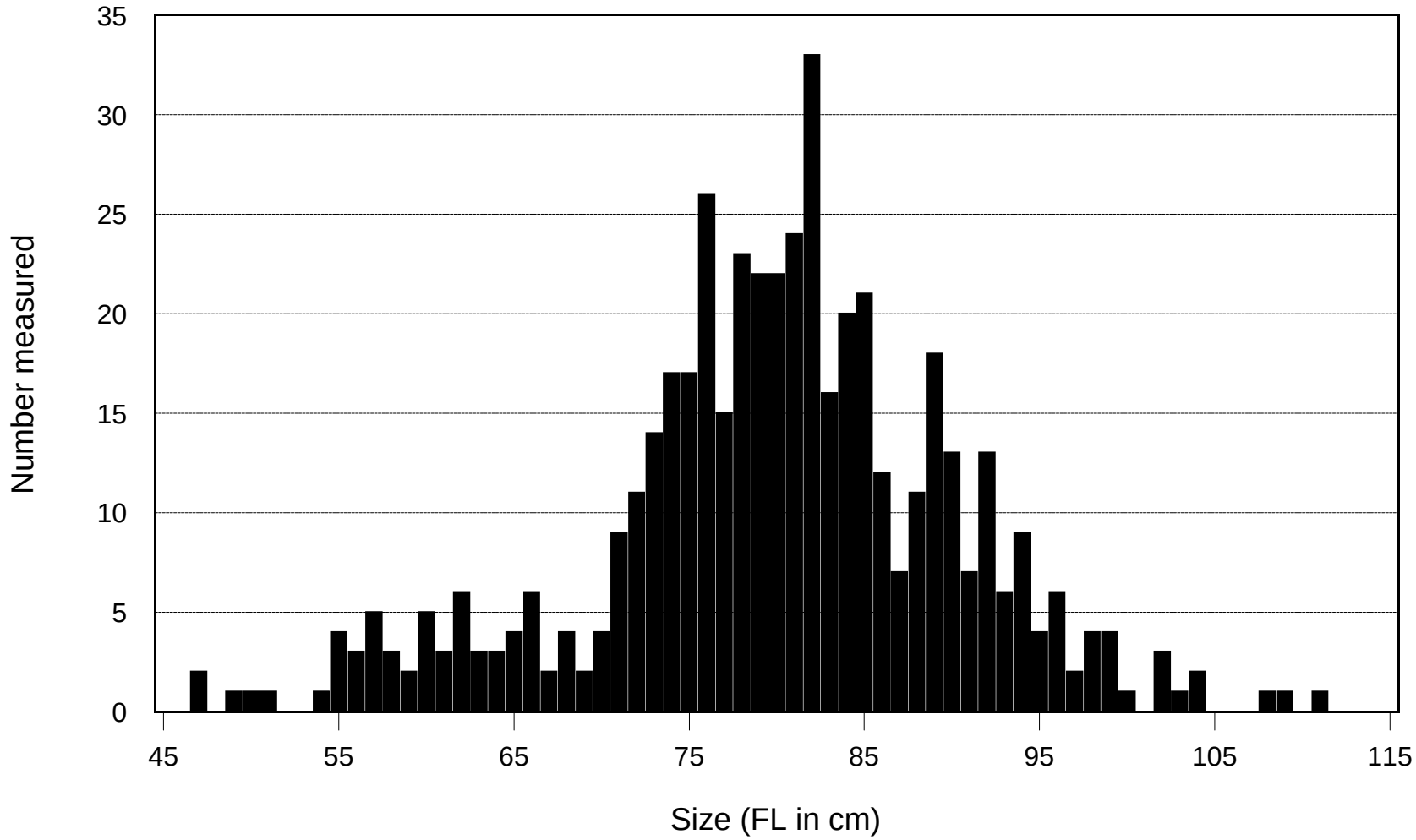

Figure 5. Size (FL in cm) distribution of male chinook salmon carcasses measured during the upper Sacramento River fall-run spawner escapement survey, October - December 1995.

Female chinook salmon length frequency

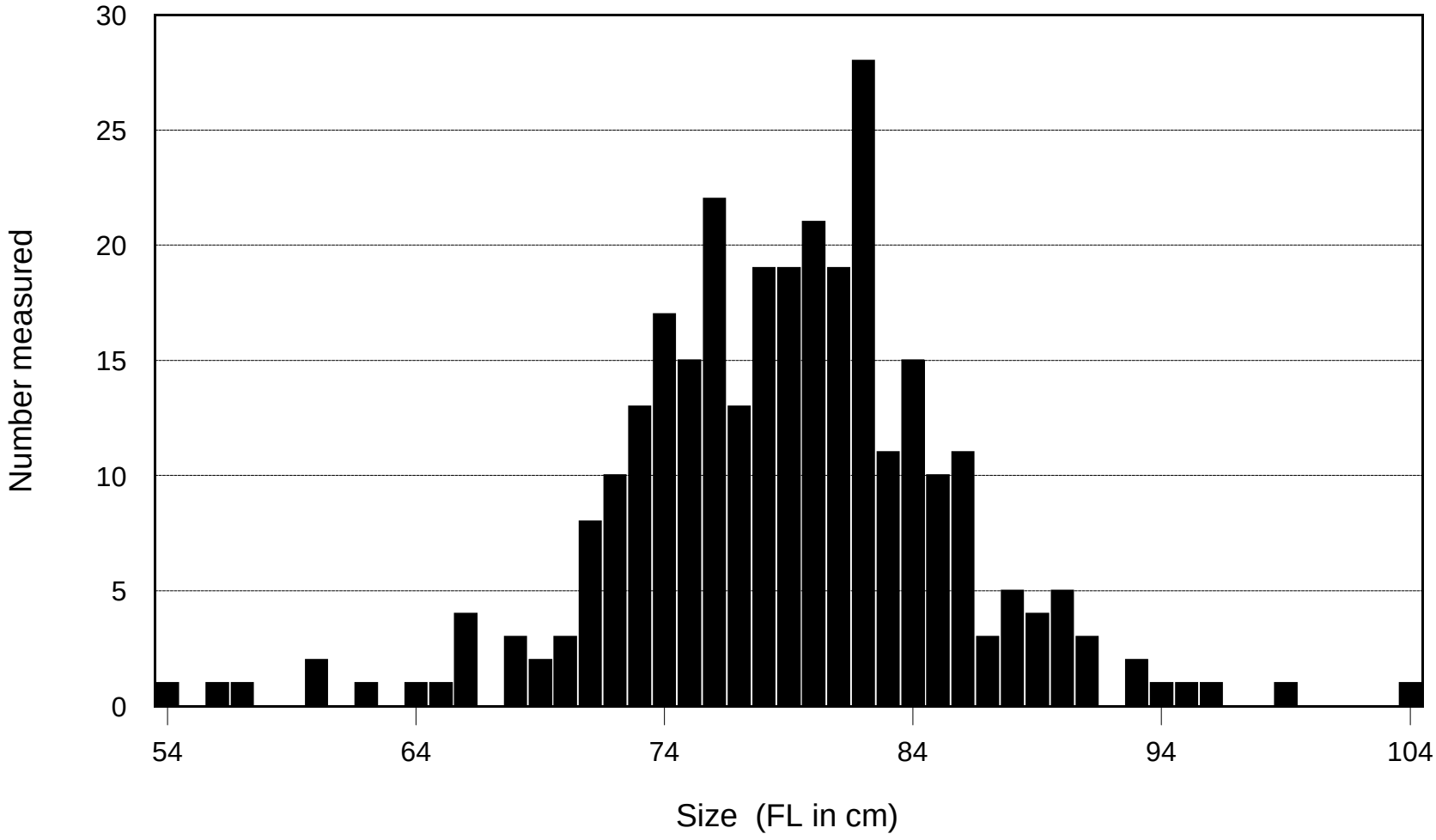

Figure 6. Size (FL in cm) distribution of female chinook salmon carcasses measured during the upper Sacramento River fall-run spawner escapement survey, October - December 1995.

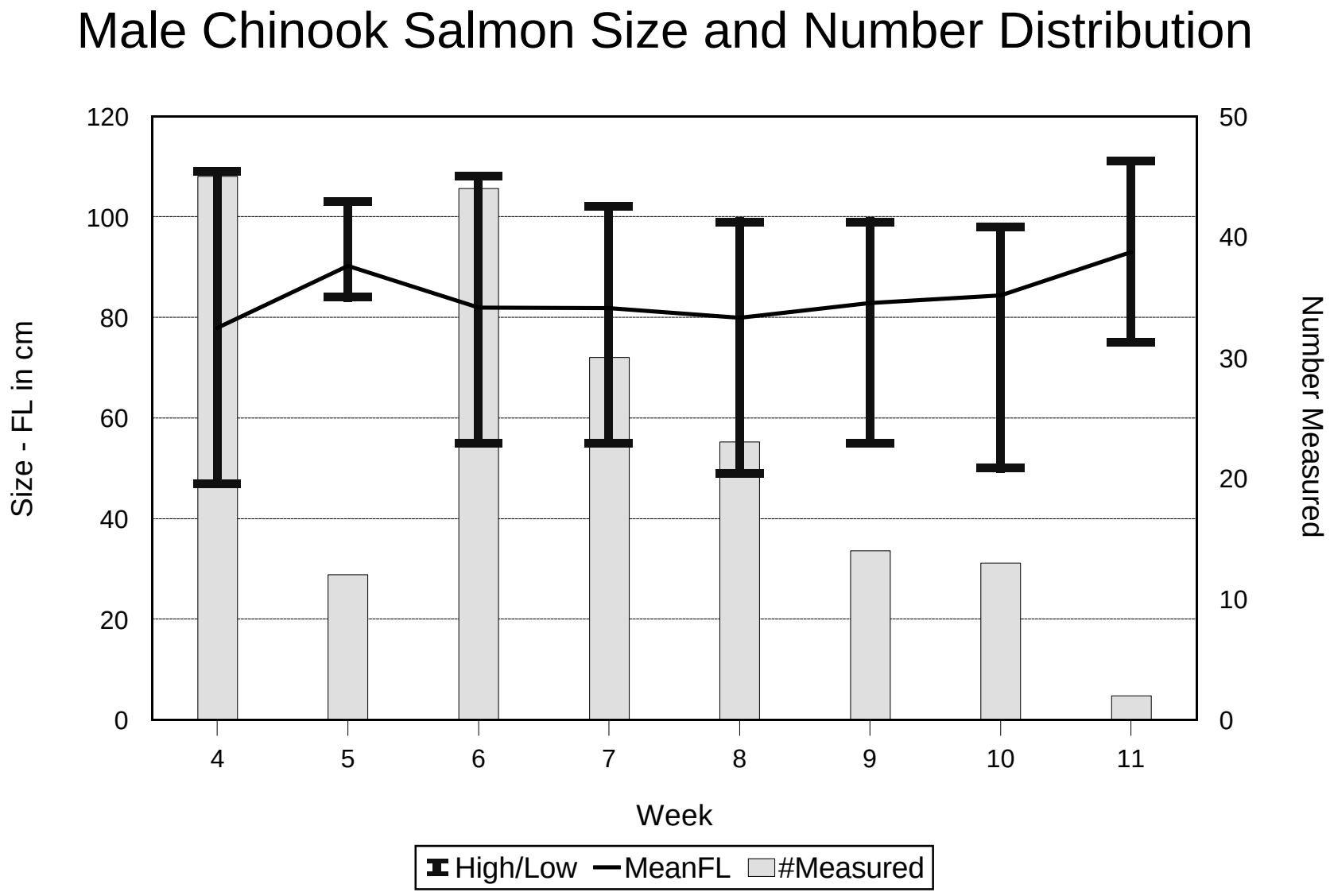

Figure 7. Mean size, size range, and number of male chinook salmon measured weekly during the 1995 upper Sacramento River spawner escapement survey, October - December 1995

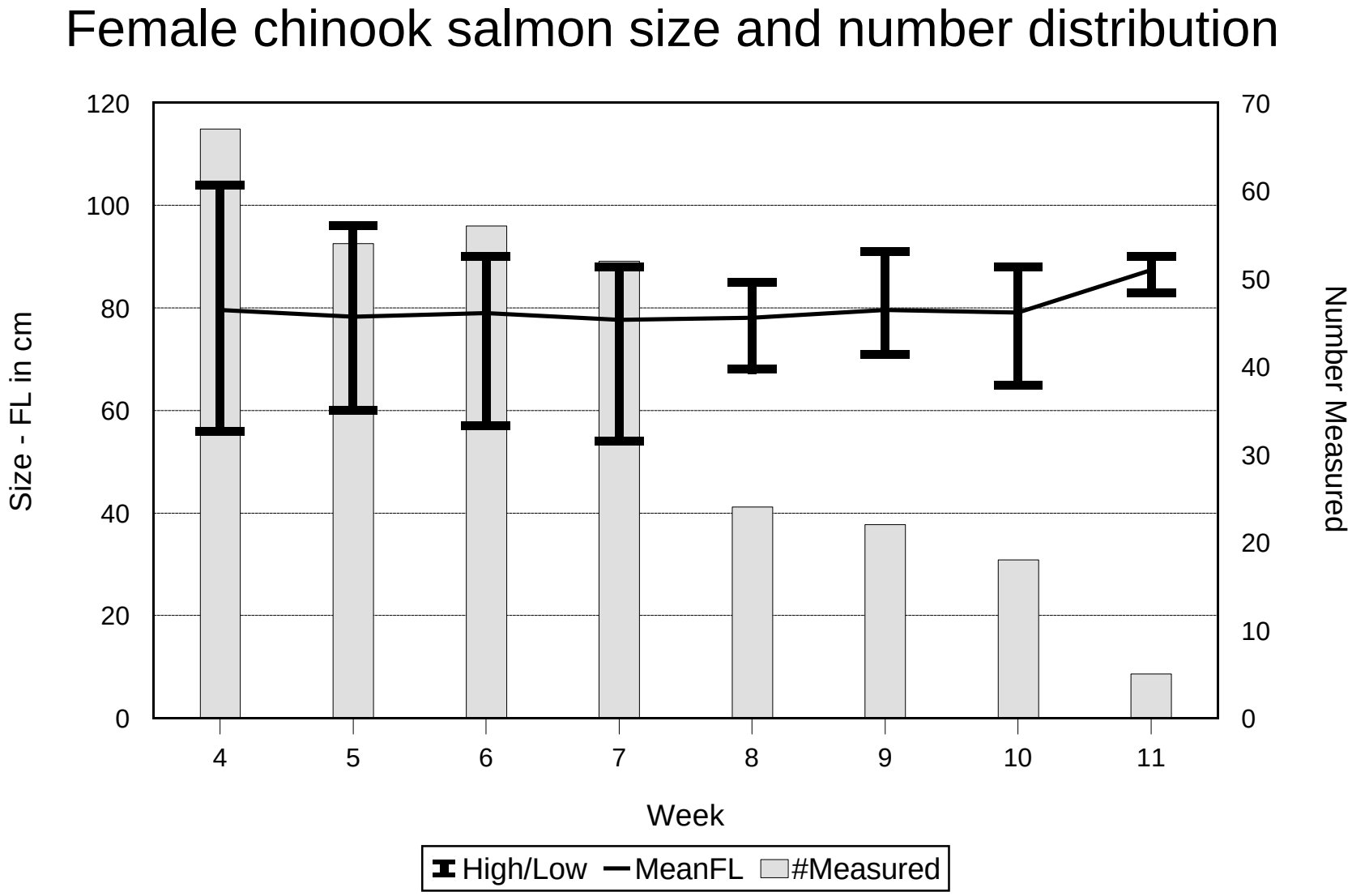

Figure 8. Mean size, size range, and number of female chinook salmon measured weekly during the 1995 upper Sacramento River spawner escapement survey, October - December 1995

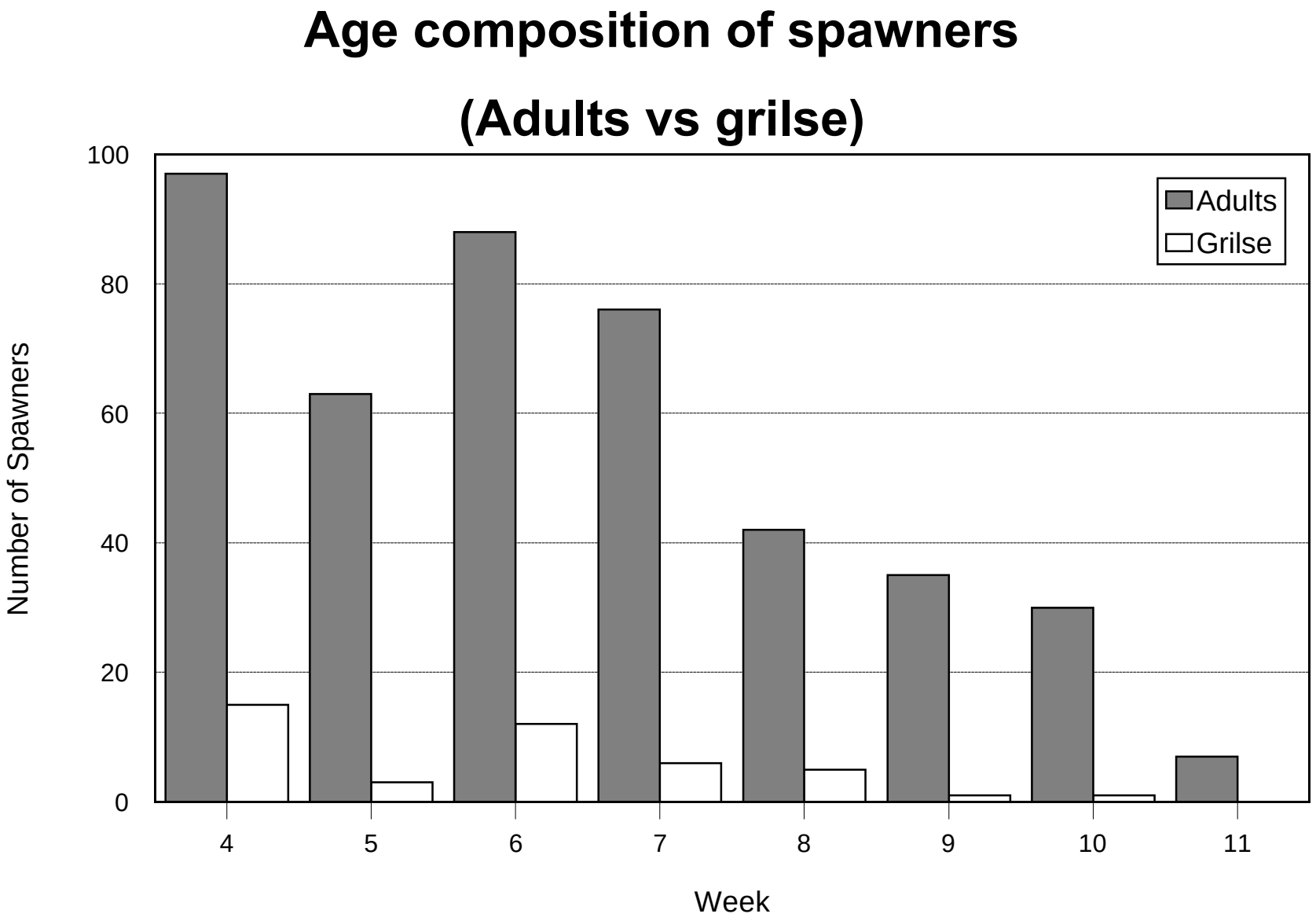

Figure 9. Age composition of fall-run chinook salmon measured during the upper Sacramento River spawner escapement survey, October - December 1995.

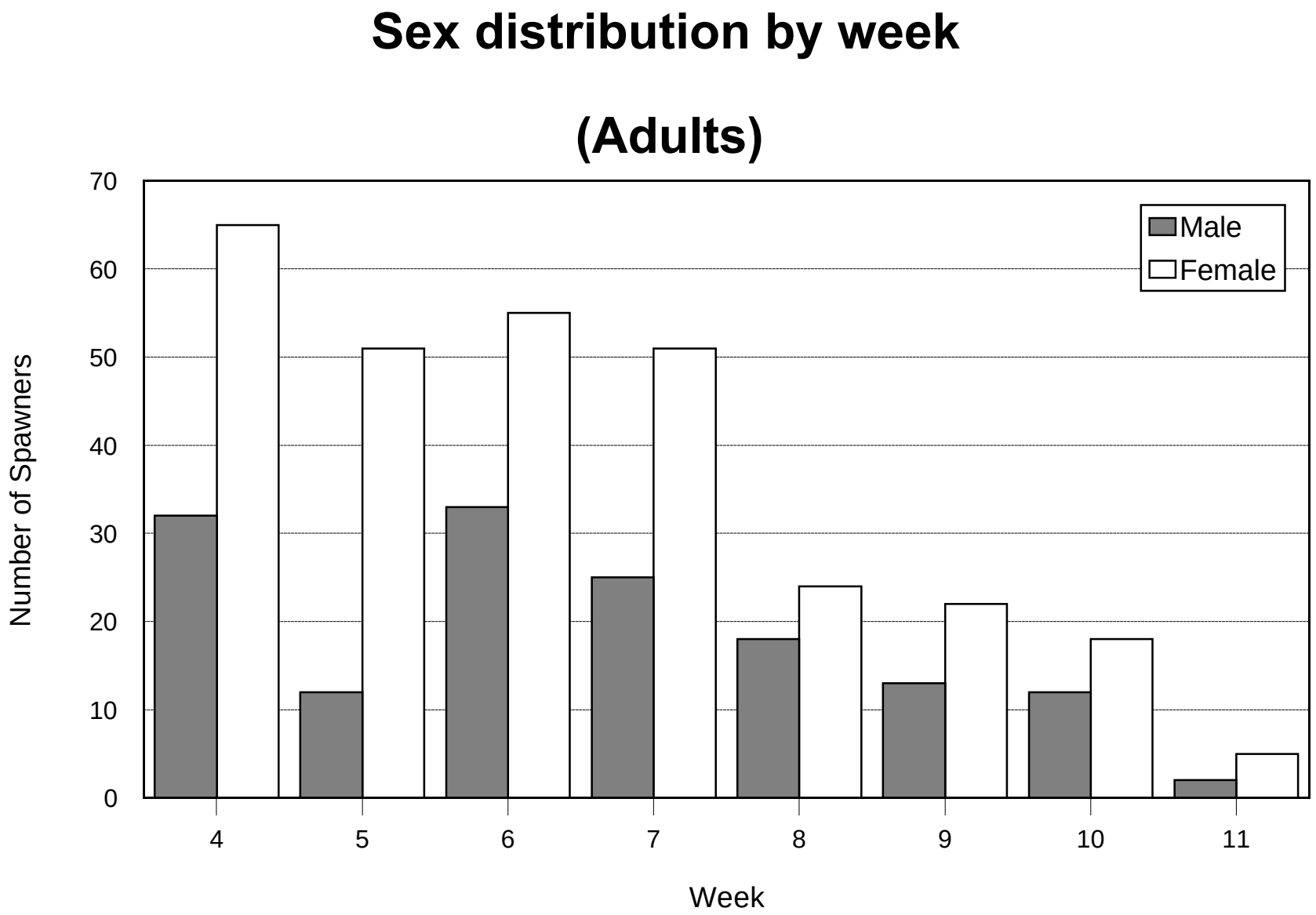

Figure 10. Weekly distribution of the sex of adult-sized fall-run chinook salmon measured during the upper Sacramento River spawner escapement survey, October - December 1995.

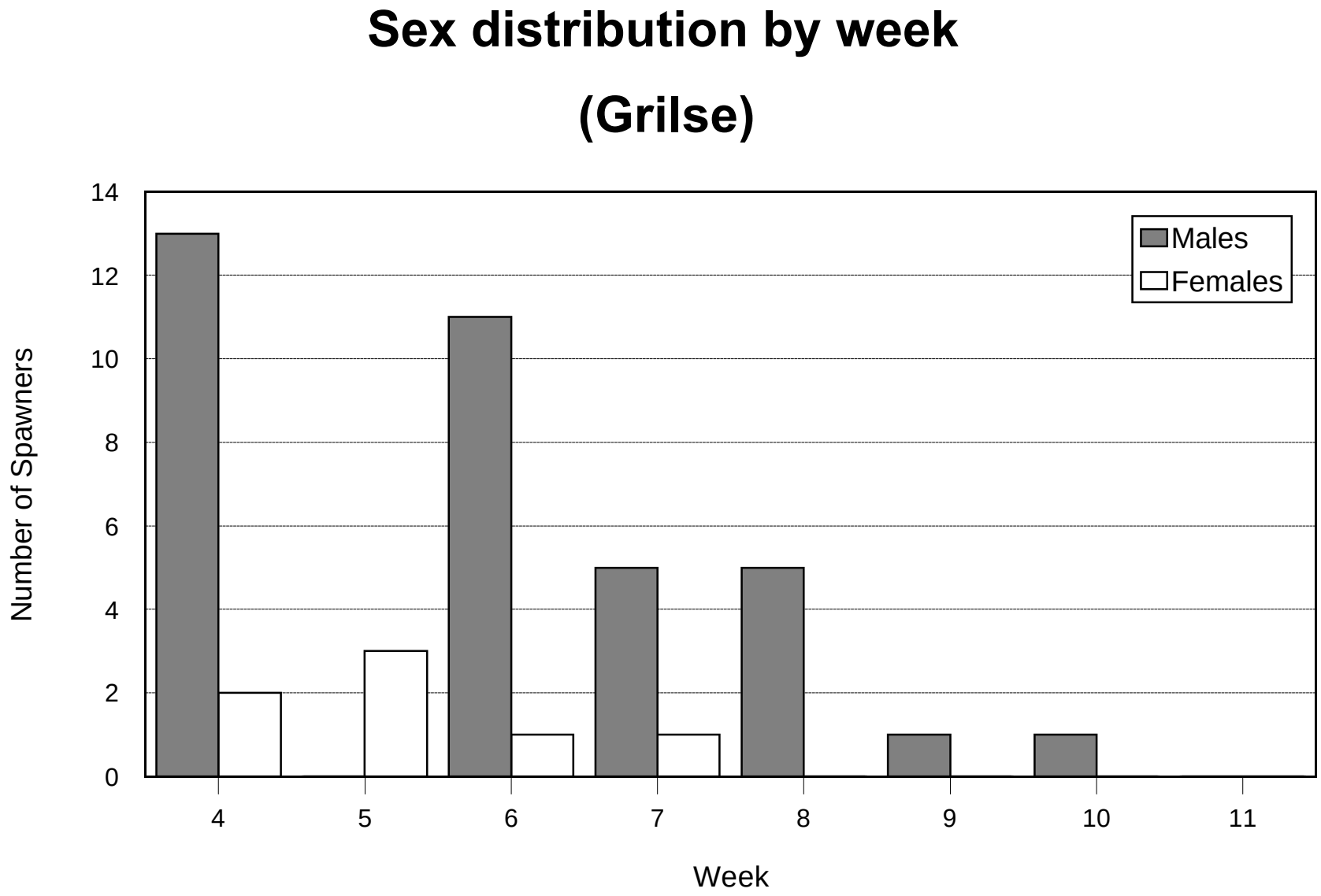

Figure 11. Weekly distribution of the sex of grilse-sized fall-run chinook salmon measured during the upper Sacramento River spawner escapement survey, October - December 1995.

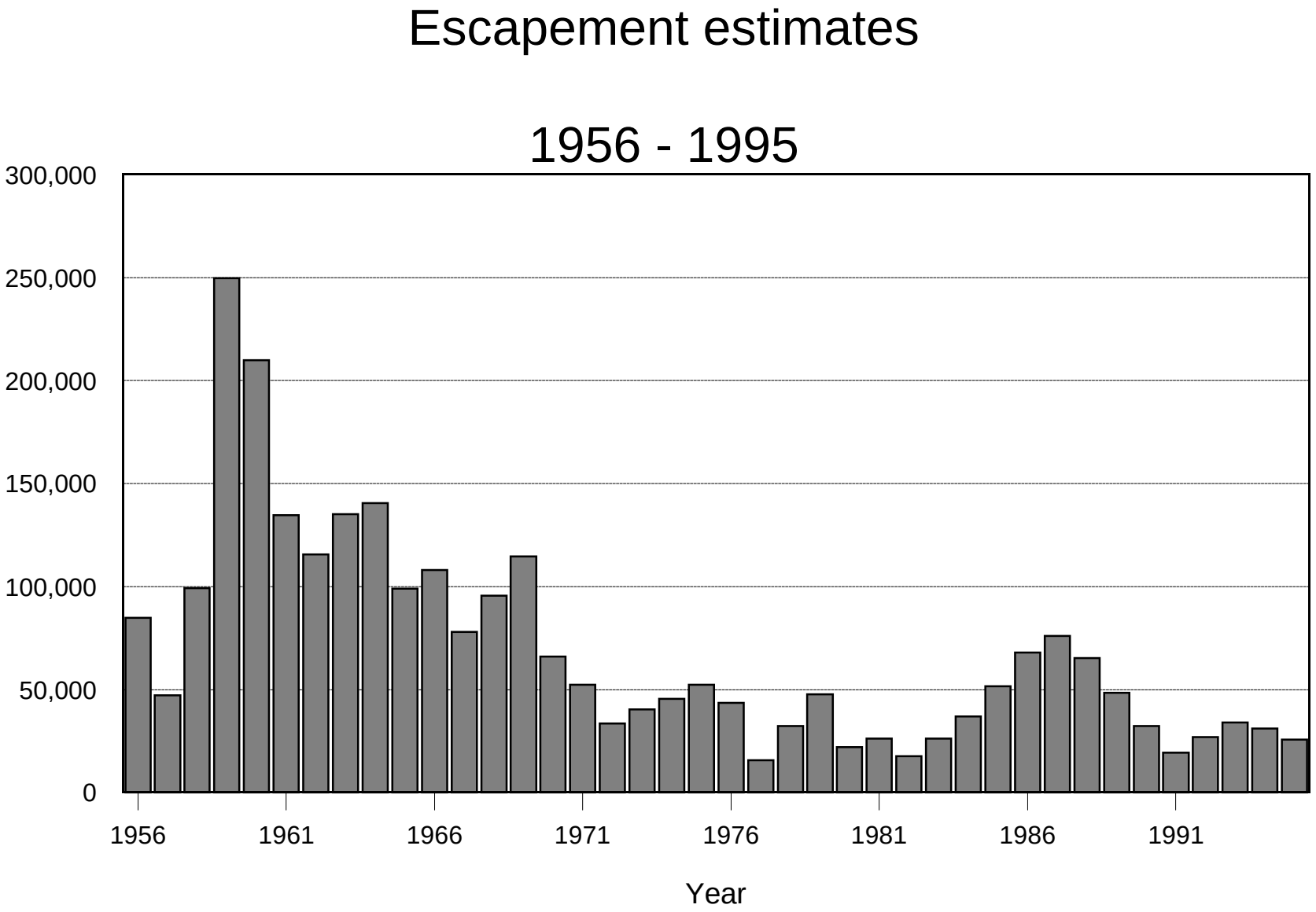

Figure 12. Summary of chinook salmon escapement (adults and grilse) in the mainstem Sacramento River from Keswick Dam downstream to Red Bluff Diversion Dam excluding tributaries (1956 - 1994).